CHAPTER

29

COVID-19 as an opportunity to make field-based earth sciences and other similar courses easily accessible and affordable

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29.1 Introduction

Rocks can talk to a keen observer and field geologists will agree with it. The geological history of our home planet, the Earth, is an accumulation of a wealth of information that has been studied and researched by the geoscientists who literally decode the language of rocks, structures, sediments, etc. The first human observer was not equipped with high technological gear to investigate rocks, but with a keen eye to unravel the geological events that the Earth has witnessed over more than 3.4 billion years of its history. This is only possible when we interact with our surroundings, and in particular rocks. A typical geological field site visit helps learners to discover the knowledge preserved in rock record, and such exercises are used to generate new data and understanding on how our Planet Earth functions (Aaisyah et al., 2020b). The interpretation of field data unravels the geological histories and provides a way to further strengthen our research goals. Field based learning stimulates excitement and initiates interest to interact more with rocks, and it has been one of the major attractions of the geoscience students (Esteves et al., 2015; Dolphin et al., 2019; Fedesco et al., 2020). However, these field based observational skills may be greatly disrupted if fieldwork activities are discontinued or completely halted, which may be due to a number of reasons. For example, it is often costly to run a field session with students, and it also requires human resources plus physical strength and health of participants etc.

Moreover, and unfortunately, the field-based courses have remained limited or unavailable to students with health and physical problems, which is a major concern that needs to be addressed. And with the emergence of COVID-19 in China at the end of December 2019, the world has been forced to take unprecedented steps to follow lockdown strategy to contain the spread of the infectious and deadly virus (Qadir & Shah, 2020). The lockdown has resulted in isolation, and as human interactions in particular face-to-face meetings are not encouraged, digital communication has emerged as a critical approach to relieve the need for physical interactions. Therefore, the birth of the global virtual space has created a quasi-world where the internet acts as "virtual oxygen" to facilitate communication and working from a distance without physically contacting each other. The online communications have raised serious issues related to education, and in particular the concerns related to the field based learning that were

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previously unexplored. Therefore, we show in this chapter that COVID-19 related crisis has emerged as an opportunity for us to relax, relook, reevaluate, and reinstate the field-based geological education related problems that we have somehow overlooked over the decades.

We demonstrate through our fieldwork in Brunei that virtual field-based exercises could aid and become vital components to the modern education system, because it enables 3D visualization of outcrop details that were previously out of reach. We have used unmanned aerial vehicles (UAV), which are popularly known as drones, to record the kilometer and centimeter scale field site observations. These data are combined with the high-resolution mm-scale field observations to create a high-resolution field dataset that could be utilized for academic and research activities. We have observed and examined the ability of undergraduate geology students to grasp the key concepts in structural geology and geological mapping by using both the traditional and virtual field learning techniques. These exercises have opened a new arena of field geology, and we believe it is important to use the digital technology and in particular UAVs, to strengthen the applicability, usability, and accessibility of field courses that are frequently interrupted due to various problems such as financial conditions, health, political lockdowns, environment (e.g. during extensive flooding, fires etc.), pandemic (e.g. Covid-19), and similar other related issues.

29.2 Background

29.2.1 Online and offline virtual field courses

With the emergence of COVID-19, virtual teaching, learning, and research activities have replaced traditional schooling all over the world. This has raised a number of questions on how to make a smooth transition from the traditional learning to online mode (e.g. Burgess and Sievertsen, 2020; Qadir and Shah, 2020). It has challenged all, and for geosciences the road is even trickier, which is primarily because of the field-based nature of courses. Historically, online learning has been debated for decades, and there is a mixed reaction from students, teachers and parents on their online learning experience. For example: should it continue and become a parallel counterpart of the face-to-face learning, or should it completely replace the traditional mode of learning (e.g. Bartley and Golek, 2004; Evans and Haase, 2001; Nguyen, 2015)? These questions confront geoscience community as well, and it requires mapping of merits and shortcomings of both the virtual and traditional mode of learning so that a proper framework is established to move forward in a progressive manner (e.g. Czujko and Henley, 2003; Locke, 2005; King, 2020).

Furthermore, the global outlook of the response and reaction to the COVID-19 crisis is heterogeneous, which is mainly because of the economic differences. For example, the slow speed of the Internet has created disruption in online learning, teaching, and communication, and this has potentially impacted millions in regions that are either remote, poor, or immersed in political lockdowns (Qadir and Shah, 2020). Therefore, the transitional journey from the traditional to online learning has opened up new frontiers to explore, research, and strategize the future planning with a solution oriented direction. This requires us to realize, map, underline, and understand that a single solution cannot be achieved to the ongoing crisis, which means we must work on both short-term and long-term strategies to offer balanced solutions that are sustainable.

29.2.2 Making geosciences accessible to people with physical and other types of disabilities

The various physical disability (here referred to as physically challenged) communities among us, have faced strict choices in all walks of life because traditionally we have designed most of the facilities for the able people. This situation is not uncommon in education, and particularly field based learning. According to the recent estimates by WHO (2011), there are more than a billion variously challenged people in the world and geoscience courses have remained less attractive to students compared to the other science and engineering degrees (Czujko and Henley, 2003; Locke, 2005). One of the reasons for this outcome is the wrong perception that only physically abled bodies can take part in earth science courses (Atchison and Libarkin, 2016), which originated from our past mistakes where we have failed to accommodate, organize and build a culture of education that welcomes all. However, this must change, and it is slowly changing (Marshall and Thatcher, 2019), and the work presented below shows one of the many aspects of making field based education accessible and affordable to all learners.

29.3 Materials and methods

We have used Google satellite data to locate two geological outcrop sites (Fig. 29.1). The first site is known as Sengkurong-1 outcrop and another is Sengkurong-2 outcrop, also locally known as the "Lion King" outcrop (Fig. 29.1). These sites are located at Kampong Sengkurong in Brunei-Muara District, and display some of the best examples of outcrops in Brunei that expose both the map and cross sectional views of the lithological contacts and faults. Therefore, these sites are ideal places for geology students to learn about geological and structural mapping. The outcrops are easy to locate, accessible, and free of vegetation (Fig. 29.1). These sites expose faults (Aaisyah et al., 2020a, 2020b), which are traceable from Google map. Therefore, the locations and the physical characteristics of the sites was suited to conduct fieldwork on foot and with the help of drones. The drone was therefore used for reconnaissance and detailed fieldwork without fearing it might crash in the thick tropical forest cover of Brunei!

The field site data were recorded by visiting the sites and mapping of the detailed structural and geological parameters, which were mainly related to lithological contacts, fossils (primary sedimentary structures are used to know the overturning of beds and way-up), dip, strike, rake, dip-direction, viewing direction, and so on. We collected the oriented aerial and detailed field photographs by carefully recording the viewing direction and scale of observation (Figs. 29.2 to 29.7). The aerial shots are taken by using DJI Mavic 2 Pro, which is an economic drone that greatly helps in mapping (Aaisyah et al., 2020a, 2020b). The drone image data are converted into 3D models for the Sengkurong-1 outcrop (Figs. 29.2–29.5), to show the usability, veracity, and quality of data. The drone's ability to capture high-resolution images and videos with vibrant colors at a commercially affordable price (USD$1,599) made it appealing to us and our mission to map details at kilometer to mm-scales. The DJI Ground Station Pro,

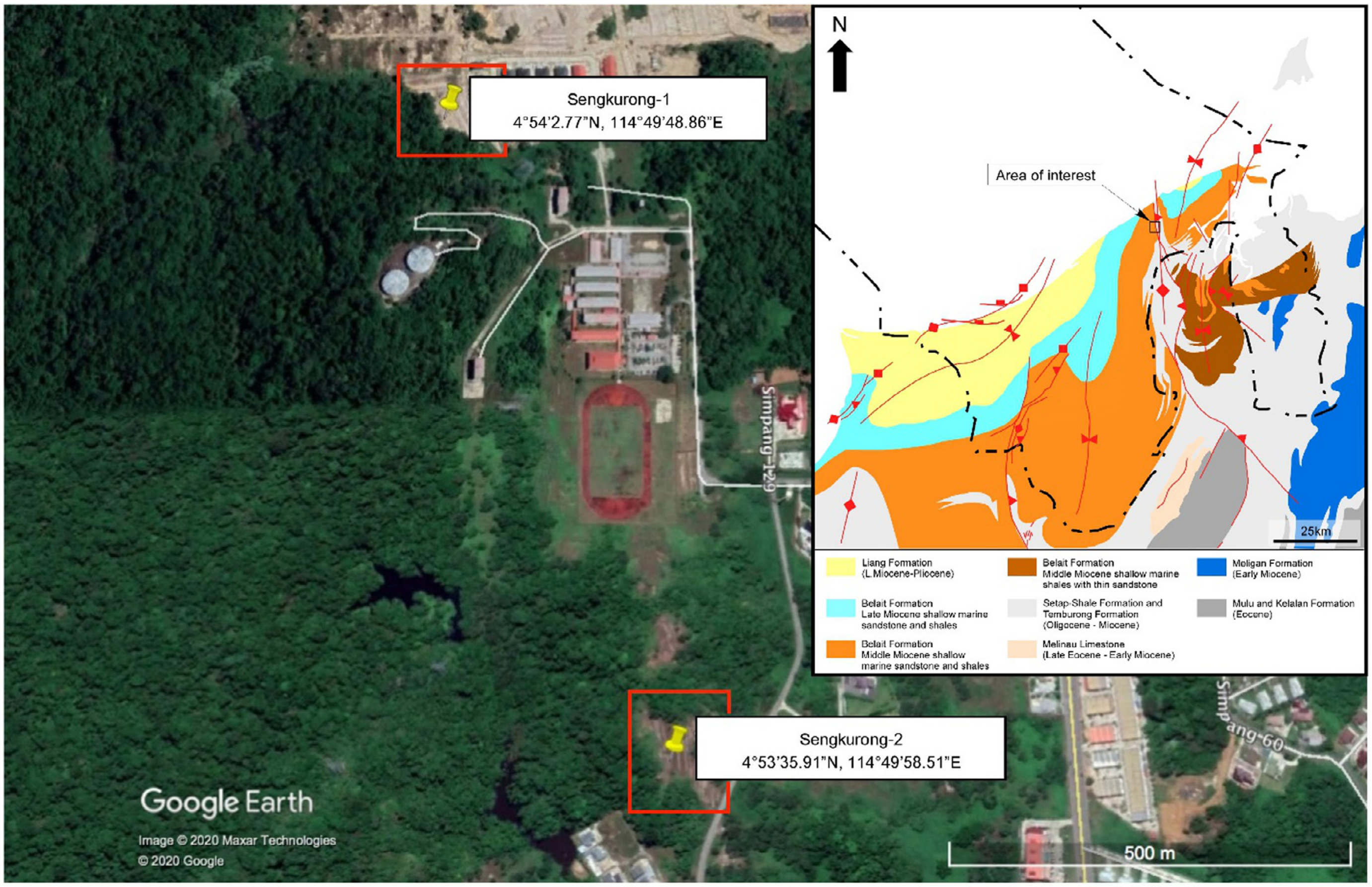

FIG. 29.1 The location of two geological outcrops in Brunei Darussalam is shown as red rectangles (Sengkurong-1 and Sengkurong-2). These sites are surrounded by housing areas and a secondary school. Data plotted on Google Earth Pro (2019). The regional geological and structural map of the region is shown at the top right [modified after Morley (2003)].

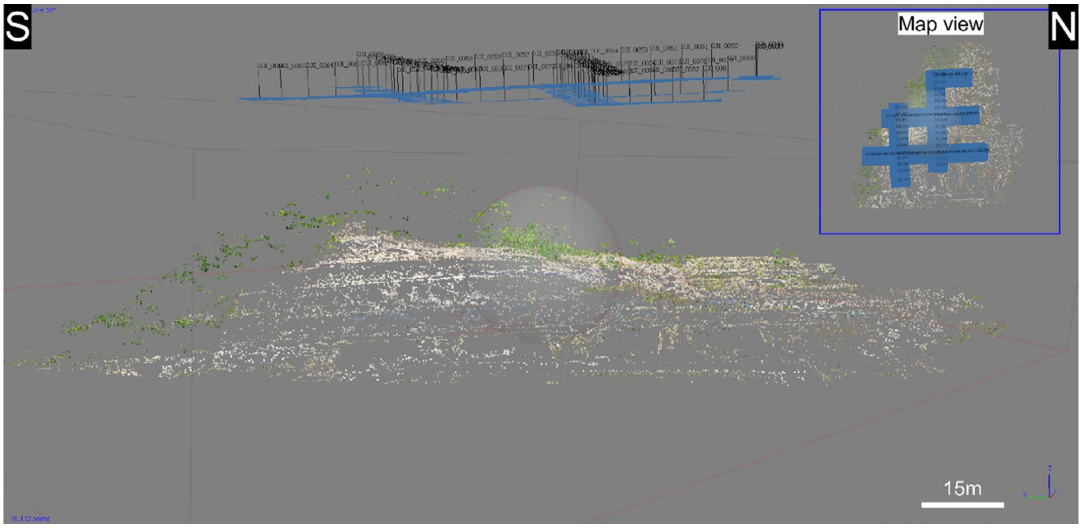

FIG. 29.2 Point Cloud dataset of the Sengkurong-1 outcrop. The flight paths of the drone are shown in blue, which recorded the images of the site.

which is an iPad app was used to generate the flight paths for the drone (Fig. 29.2). The points of interest were selected and the waypath was generated by the app itself. Images of the outcrop were taken at equal intervals along the path set by the app at a height of 70 m above ground level and it covered 1.82 acres. In less than 5 minutes, a total of 67 photos were taken along the flight path at a shooting angle of 90°. Once the image capturing process was completed, the data were later imported onto Agisoft Metashape software, aligned, and stitched to create the point cloud model of the outcrop (Fig. 29.2). Each point represents a feature that was identified in more than one photo. The setting chosen here is at the highest accuracy to give more details on the outcrop. After rendering of the data, the Dense Point cloud was used to show the "solid" image of the outcrop generated after the point cloud (Fig. 29.3b). This option is rendered at ultra-high quality to ensure no data is missing from the structural details.

The UAV model that we have used does not automatically provide structural orientations (e.g. dip direction of geological units etc.), therefore, the structural and geological details were recorded in the field, and later annotated on the images using the editing software Photoshop and Canvas-X (Figs. 29.2–29.7). However, it does provide geographic directions, which makes mapping easy.

29.3.1 Testing of the virtual versus traditional fieldwork learning

We took 30 undergraduate students of B.Sc. Geology at University of Brunei Darussalam to the same field site that we have surveyed for the virtual field exercise to test the pros and cons of replacing fieldwork with virtual field. We asked the students to complete a field assignment within 3 hours and return it with all the required details on it. The same group of students were given images, 3D virtual tour, and video of the sites to record the details in the same assignment that we used earlier in the field. The kilometer to millimeter scale outcrop details were made available to them. The time was fixed, 3 hours to complete the assignment. The assignment was collected, and graded. The students were also given the PlayDoh models to reconstruct the structural and geological history of the sites, which was done in the subsequent weeks to test the learning with interactive 3D clay models.

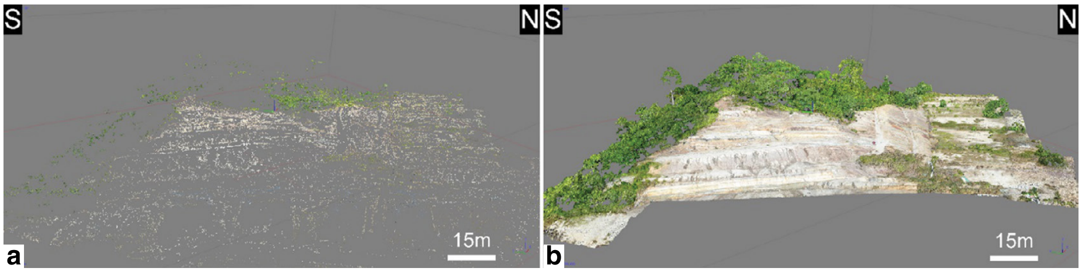

FIG. 29.3 The difference between point cloud (left) and dense point cloud (right) images of the Sengkurong-1 outcrop.

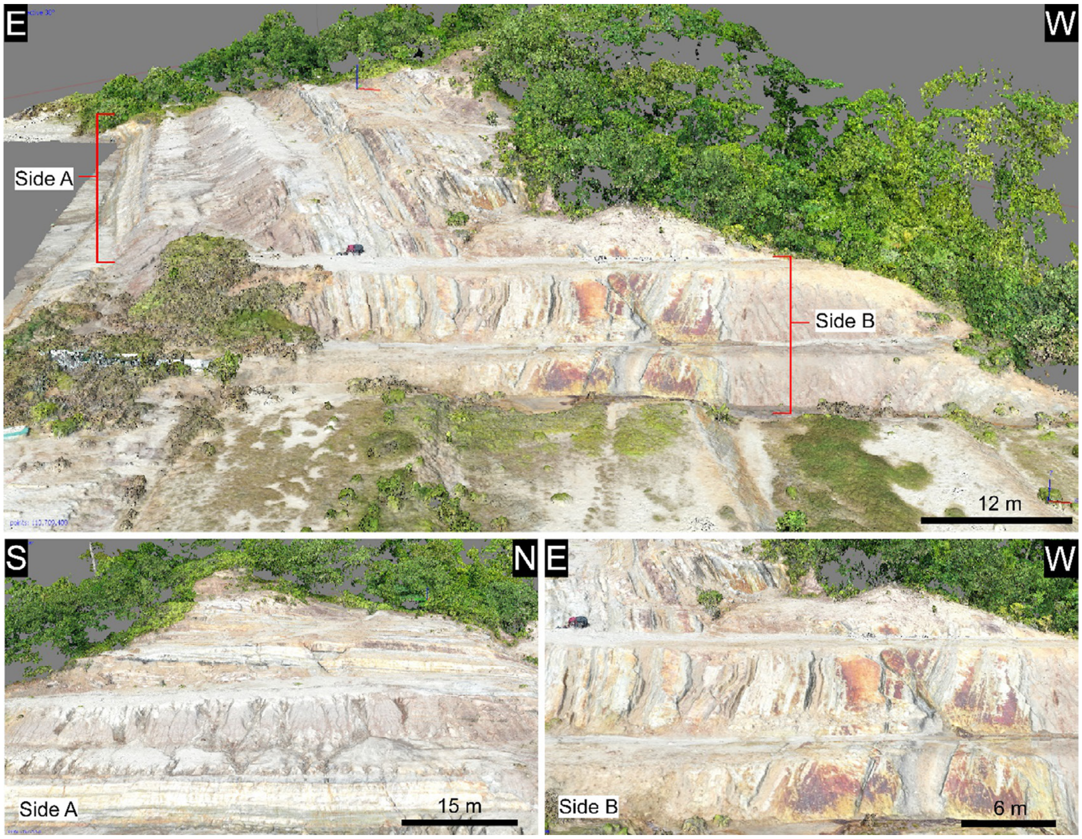

FIG. 29.4 Close up image of Fig 29.3b shows the finished 3D model of the Sengkurong-1 outcrop. The images at the bottom are the close-up image for Side A and Side B (left to right).

29.4 Results and interpretations

The geological and structural mapping that we have conducted using static and dynamic photography and videography has revealed a wealth of geomorphic and geological information that can be preserved for multiple purposes. The data shown here are captured from two sites in Brunei (Figs. 29.2 to 29.7) that show strongly tilted lithological beds, which are mainly composed of sandstone and shale and the thickness varies from a few centimeters to more than a meter. The Sengkurong-2 outcrop offered a rare opportunity for us to generate map and cross sectional views of the entire outcrop, which was favored by students because it was easily accessible *via* road and it has no vegetation, which made the mapping exercise easier on foot as well as by drone. Both the sites show steeply dipping sedimentary layers that are cross-cut by steeply dipping faults (Figs. 29.2 to 29.7), and the details on fault zone structures are beautifully preserved and were easily understood by students. The drone images (Figs 29.4–29.6) show the overall outcrop pattern, which was previously impossible for us to show because we were unable to capture the entire outcrop using handheld cameras, plus, it was unaffordable for us to fly aerial vehicles above the geological sites in the past. This has dramatically changed now by drone coverage, and it has helped us to teach mapping with more interactive learning abilities.

The regional map view of the outcrop (Fig. 29.1) has shown the bedding layers and faults in aerial perspective, which was followed by the detailed mapping and we recorded a few meters of left-lateral strike-slip faulting at the Sengkurong-2 outcrop (Fig. 29.6). The detailed fieldwork allowed us to map the structures at the millimeter accuracy (Fig. 29.7). The clay smears, slip surfaces, and other fault related structures can be easily traceable. Therefore, the drone and traditional camera based photography has mapped the kilometer and mm scales of the observations, which proved to be a very useful exercise for teaching and learning, and a valuable data for research. Similarly, the observation of the details on the primarily sedimentary structures were also possible by zooming on the particular outcrop photograph, which are captured at a very high resolution. These data were used to know the way-up of the lithological units, which are tilted at steep angles. The details on fault zones are also measurable, and could be quantified by using the detailed mapping of the fractures, slip planes, etc. (e.g. Fig. 29.7).

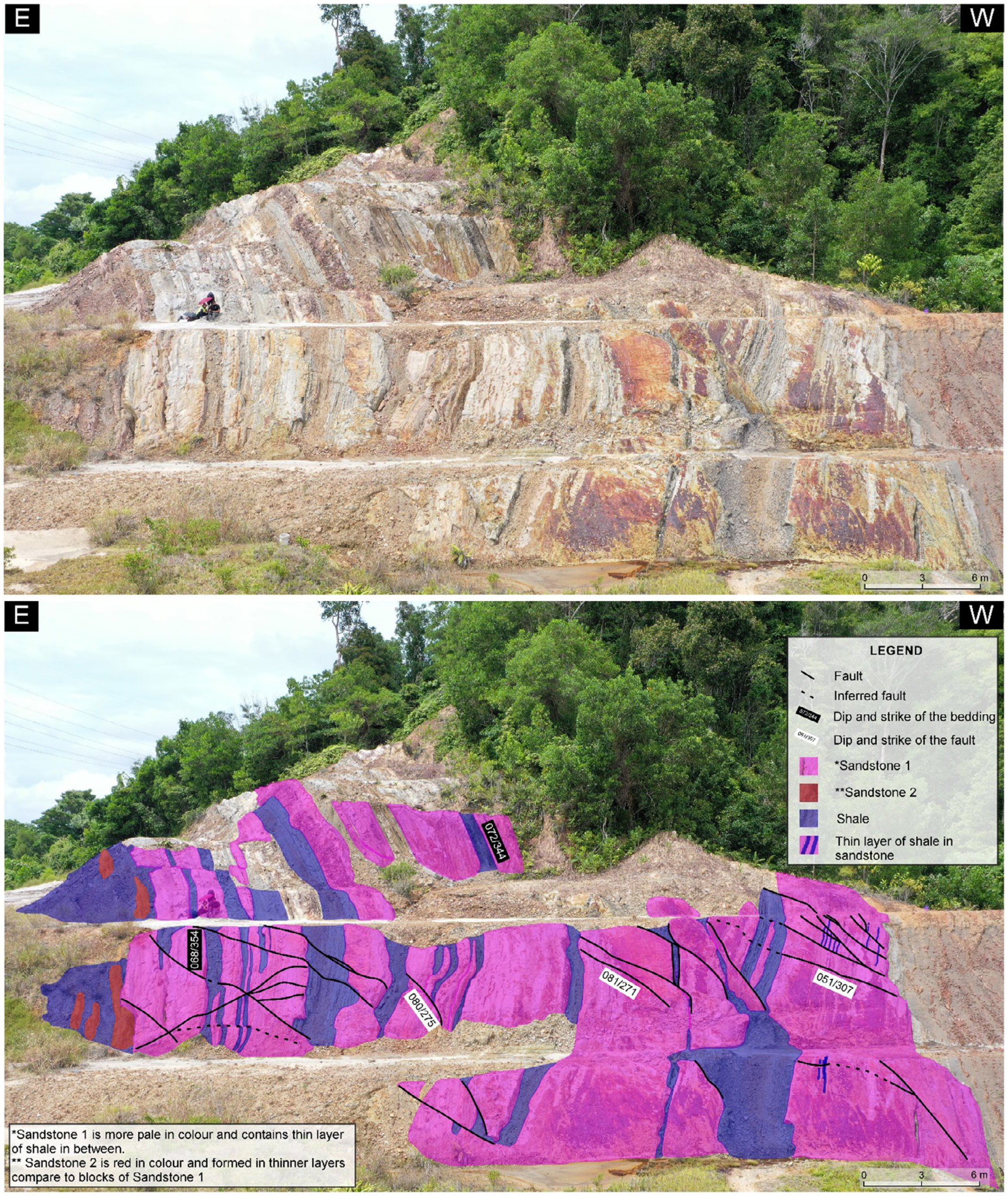

FIG. 29.5 Drone derived imagery of the Sengkurong-1 site (location in Fig. 29.1) shows the uninterpreted image (top) and interpreted image (below). A number of faults are exposed (black lines) that have displaced the lithological units as observed in both the cross-section and map views.

29.4.1 Virtual versus traditional fieldwork

We discovered that fieldwork is exhausting in Brunei because of the tropical weather where temperature can go up to 35°C and humidity remains high. These conditions remain more or less unaffected throughout the year, which greatly impacts the frequent field visits. Unfortunately, both the students and teachers were unable to tolerate the weather elements in the field for long hours, and two of the students stopped working in the middle of the field exercise. Same was true for our professor, who often gets heat stroke after a typical 4 hours of fieldwork session in Brunei, which was not observed in NW Himalaya where he worked typically for more than 7 hours a day. This means that weather can impact the geological fieldwork, which can be partially solved by virtual field site visits (this study), and introduction of campervans with facilities to cool down during the field breaks.

FIG. 29.6 Left: drone derived map-view of the entire Sengkurong-2 outcrop. This site is also locally known as the "Lion King" site. Right: a high-resolution shot with more details on the portion of the outcrop that is beside the road (visible in the lower left corner), and was easily accessible. Locations are shown in Fig. 29.1.

It was encouraging to see that students performed well in field assignments at both sites, where they recorded dip, dip-direction, thickness of sedimentary beds (true and apparent), and structural parameters that includes dip, dip-direction of one major fault along with foliation, fractures, and lineation. However, such details were more coherent and nicely done in virtual field exercises, which was also encouraging. We discovered that onsite field visits by students have potentially many advantages as it opens a broader perspective of the fieldwork related realities, which includes time management, responsibility to work on deadlines, pre fieldwork planning, physical presence to "feel" the rocks, bonding with classmates and teachers, etc. However, the major drawback was the time limitation because students cannot spend more than 3 hours in the open sun due to health concerns such as heatstroke, sunburn, exertion, etc. Two students were unable to climb the outcrop because of their weight problems, and it raises an important issue that onsite fieldwork is not suitable for students who are physically challenged, ill,

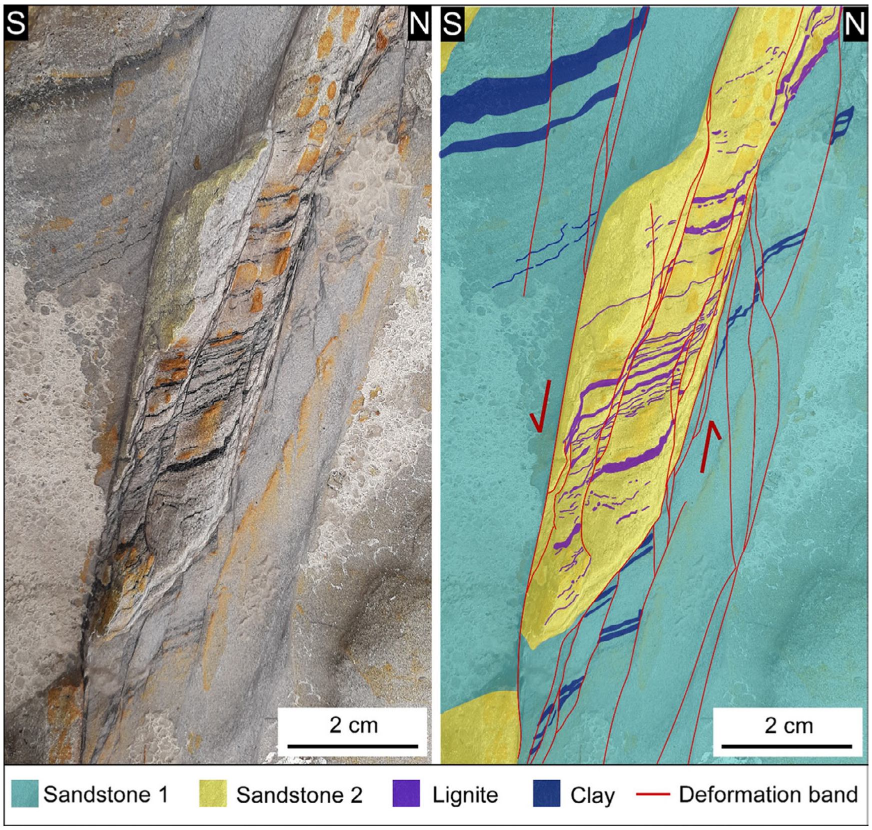

FIG. 29.7 Detailed structures related to the strike-slip faulting are observed along the strike of the fault at the Sengkurong-2 outcrop. Location of the outcrop is in Fig. 29.1.

or have similar concerns that limit their physical presence in the field. These concerns are however nicely resolved by the virtual field exercises where we have observed that students showed a strong interest in learning. For example, the field assignment exercises were properly and nicely done in the class compared to when conducted in the field. Out of 30 students, only 5 students recorded orientation of foliations, and slip surfaces, and all others just completed the dip amount and dip direction of the major fault. The typical submitted assignment lacked a proper scale of mapping, and small scale observations (e.g. fractures, lineations, foliations, and slip surfaces) were routinely missing, this was phenomenal. The major fault was mapped by all students but more like a solid line than what it is in reality: a zone of deformation. This however changed dramatically when we used virtual field data and asked students to draw and trace the details on photographs using drawing software or tracing paper. The end product was clearly an improved version (Fig. 29.3 shows one such example), and more importantly most of the students did the assignment rightly. Out of 30 students 25 students recorded details on slip surfaces, clay smears (something which was totally ignored in the field), and fault displacement. We also observed that students recorded tangible structural details on each field photo that was given to them. We think it is primarily because in a typical classroom setting the students are relaxed and place more emphasis on learning and understanding rather than focusing on mere technical skills to measure and finish the assignment. We have seen a sharp increase in the number of questions raised by the students in the virtual field class, and this was minimum at the field site, which again proves that students used critical thinking in the classroom to understand the field realities that were somehow masked in a typical outdoor fieldwork environment.

The interesting part of the learning was revealed when we used PlayDoh models during the subsequent weeks to reconstruct the stratigraphic, geological, and structural details that they have observed in the field. The students were extremely happy, focused, and did the job exceptionally well, and the often difficult aspects of the structural geology were easily grasped by the students. For example, students reconstructed the tilting of the beds, and used the primarily sedimentary structures to know the younging direction of beds, and then tilted the beds accordingly. Their vision of investigation quickly moved from the outcrop scale to the regional scale when we asked them to write about the geological and tectonic history of the region.

29.5 Discussion

The fieldwork data produced in this study show that virtual field exercises are not only important but an extremely vital component of teaching in the modern times because it solves problems that are otherwise difficult to resolve. We have shown that geological data acquired using drones are highly useful to capture details that are usually impossible to record in a typical field session because of time constraints, inaccessibility, complex terrain conditions etc. The aerial drone coverage of the outcrop captures the larger view, which makes teaching easy because students can observe the 3D geometry of the entire outcrop that is usually difficult to comprehend in the field (e.g. Fig. 29.5). The learning assignments that we used have shown that students have applied a deep critical thinking approach to understand and interpret the outcrop details and link it with the regional geology and deformation history. The outcrop exposes a Miocene sedimentary sequence that has been faulted, and using the virtual outcrop details the students were able to map the structural details (e.g. bedding dip, dip-direction, true/apparent thickness of the fault, bedding, plus foliation, lineations etc.). The measurements could be done by a conventional clinometer as well as an open source application known as ClinoMov, which are both used to measure the azimuth and inclination of various primary and secondary structures. This suggests that field conditions can be reconstructed in the class room with more accurate results. The details are even better reflected in the classroom environment where students can accurately trace the structures (e.g. Fig. 29.7). The use of modeling clay (PlayDoh) makes it easier to understand the geological and structural history because it allows reconstruction from the start of the sediment deposition until outcrop exposure. The two sites that we have shown clearly indicate drone coverage, high resolution imagery, and PlayDoh model have drastically improved the understanding of the field conditions, and students have used these data to grasp the basic to complex geological concepts with ease. However, this was only possible when we recorded the data with proper orientation (Figs. 29.2–29.7). This means that structural orientations and scale must not be distorted at any cost, if virtual classrooms are used to replace or supplement the traditional field studies. We therefore, think that digital, and drone footage should be properly acquired and then it will complement the field realities, and could be used in academia as well as in research.

We think there are some serious disadvantages of digital geological mapping courses, and those are particularly related to the ambiance in the field, which gives a different perspective of the field conditions. Therefore, the traditional fieldwork should not be completely replaced by the virtual field exercises. Digital tools and virtual 3D field data are important components that could aid in making geological fieldwork affordable and interesting to many. This is particularly true of people who are somehow (e.g. physically challenged, with health or travel limitations, financial problems etc.) unable to attend field related courses. The hot and humid weather conditions (this study) can impact geological fieldwork, and we think similar weather conditions (e.g. too cold etc.) can also badly impact the learning at field sites. These problems can be partly resolved by virtual field site visits (this study), and by the introduction of campervans, which could facilitate easy fieldwork in otherwise risky environmental conditions.

We also realized during the course of this study that it is important to include recording and archiving of digital mapping as a standard procedure during any mapping exercise to make it available to users.

29.6 Conclusion

The work presented in this chapter is a small attempt to show that field sites can be converted into digital learning but only if the field data are acquired with structural orientations intact, otherwise, it will not help in understanding the various geological processes based on the field data. The studied geological sites only expose faulted sedimentary sequences, which is why it was easy to use clay models to supplement the learning ability of students, and such an approach may not be easy in regions that expose highly deformed and metamorphosed rocks.

We show that virtual field based courses can greatly help in minimizing the decades old problems and gaps in the field based learning primarily because it makes it more friendly, accessible, and affordable to most of the students, and in particular those who have been traditionally marginalized. The usage of technology could greatly help in bringing out the best of the field based learning, which could serve as a new platform for the change that we need the most. Geological field sites could be converted into digital formats with aerial and detailed field scales of observations, which could be improved and translated into more interactive learning exercises (Tremayne & Dunwoody, 2001; Sicilia et al., 2005; Markowitz et al., 2018). These exercises could metamorphose the field learning transition that we need, and may motivate teachers to engage students with various physical and other problems that often hinder field site visits (Weisgerber, 1990; McCann, 1998). The students could use technological gadgets to improve their field experience, which can be more entertaining by converting it into virtual 3D models, immersive Virtual Reality (VR) etc. (Markowitz et al., 2018).

Acknowledgement

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Google Earth Pro 9.3, 2019. Figure 1. The location of two geological outcrops in Brunei Darussalam is shown as red rectangles (Sengkurong-1 and Sengkurong-2). These sites are surrounded by housing areas and a secondary school. Satellite map. Retrieved from: https://earth.app.goo.gl/Gzwv8r.

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